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Design of an RF power extraction device for the CLIC test facility.

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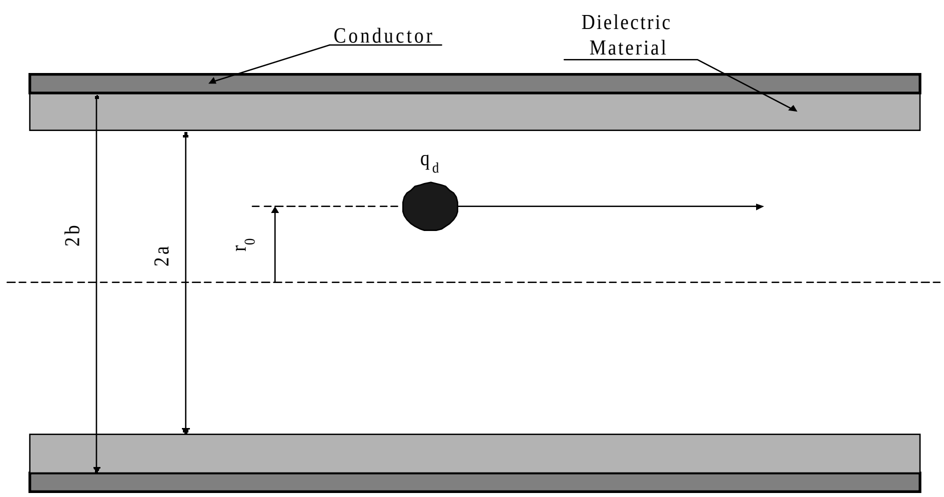
Abstract: Using dielectric structures to extract rf power for two beam acceleration has been discussed before [ANLHEP/WF-186]. With the current CLIC beam and future AWA beam, one could generate a few hundred MW rf power in a straightforward way. Recently, I have had the chance to talk with H. Braun of the CLIC test facility, and there is a mutual interest to test the dielectric based rf transfer structure concept. In this note, we discuss the design parameters for the dielectric transfer structure and some possible experiments.

1. The schematic



Here we use the same definitions as in CLIC note 364.

$$\frac{R}{Q} = \frac{4E_{z0}}{q_d \varpi} \qquad (1)$$

Since we can obtain E_{z0} by simply evaluating equation (1), calculating R/Q is straightforward.

Then the rf power generated can be determined

$$P = \frac{l_s^{\,2}\omega}{4c}\left(\frac{q_b}{T_b}\right)^2\left(\frac{R'}{Q}\right)\left(\frac{1}{\beta_g}-1\right)F^2(\sigma)$$

where l_s is the length, T_b is the bunch spacing, β_g is the group velocity and $F(\sigma)$ is a Gaussian form factor.

2. Choice of dielectric materials

Based on our previous experience, we would choose Cordierite and Steatite as our dielectric materials for the following reasons:

- Resistance to charging from intercepted beam halo.
- Rf dielectric properties insensitive to radiation dose.
- The breakdown voltage is known to be > 15 MV/m and is probably much larger.
- Can be manufactured and machined easily.

Corderite can be obtained from TRANS TECH in Maryland with dielectric constant of 4.5 and loss tangent of 0.0002 (much better than tabulated in the CRC data book). These properties have been verified in our Lab.

Steatite with dielectric constant of 5.8 and loss tangent of 0.0001 can also be obtained from commercial vendors.

3. Design of a 15 GHz device

Although CLIC plans ultimately to use 30 GHz rf, it presently makes more sense for us to develop a 15 GHz test structure. The AWA group already has all the couplers, waveguides and directional couplers available for 15 GHz work. We do not have access to a 30 GHz network analyzer required for bench measurements of coupling, etc.
Using equations in section 1, we can calculate R/Q and power generated using CLIC test facility parameters. The following table gives all the relevant parameters.

		Comment
Charge per bunch q_b	10 nC	Can vary up to 13 nC
Bunch spacing T_b	333 ps	Total 40 bunches (13 ns)
Structure length	20 cm	
Inner radius a	5 mm	Can be machined to 0.025 mm
Outer radius b	7.38 mm	Can be machined to 0.025 mm
Dielectric constant ε	4.5	Cordierite
Loss tangent δ	0.0002	
Group velocity	0.28	
Attenuation of the structure	0.35 dB	
Power generated	150 MW	
Peak deceleration field	30 MV/m	Breakdown voltage unkown at this level.

4. Design of 30 GHz structure

We have also calculated 30 GHz transfer structure using the same dielectrics.

		Comment
Charge per bunch q_b	10 nC	Can vary up to 13 nC
Bunch spacing T_b	333 ps	Total 40 bunches (13 ns)
Structure length	20 cm	
Inner radius a	4 mm	Can be machined to 0.025 mm
Outer radius b	5 mm	Can be machined to 0.025 mm
Dielectric constant ε	4.5	Cordierite
Loss tangent δ	0.0002	
Group velocity	0.41	
Attenuation of the structure	0.53 dB	
Power generated	140 MW	
Peak deceleration field	40 MV/m	Breakdown voltage unkown at this level.

5. Power transfer

In the last few years we have developed a new rf coupling scheme for this class of devices. The structures we are describing here use relatively low permittivity materials and are thus much easier to optimize coupling than the tubes we have successfully made so far. We believe it is straightforward to obtain high coupling efficiency and wide bandwidth (500 MHz) for the strucures described above.

Summary

We have designed new dielectric loaded transfer structures for proof of principle tests of a CLIC-like two beam accelerator concept. Initially we would construct a 15 GHz structure because of the availability of test equipment and rf hardware. If the 15 GHz test is successful, we will proceed to construct a 30 GHz dielectric device. According to our calculations, in excess of 100 MW rf power can be easily generated in this structure.